PIC of the 'Lith-er…PIC/Coccolith Algorithm Advances for MODIS and VIIRS for Evaluating the Global Ocean Carbonate Budget: Three Vignettes

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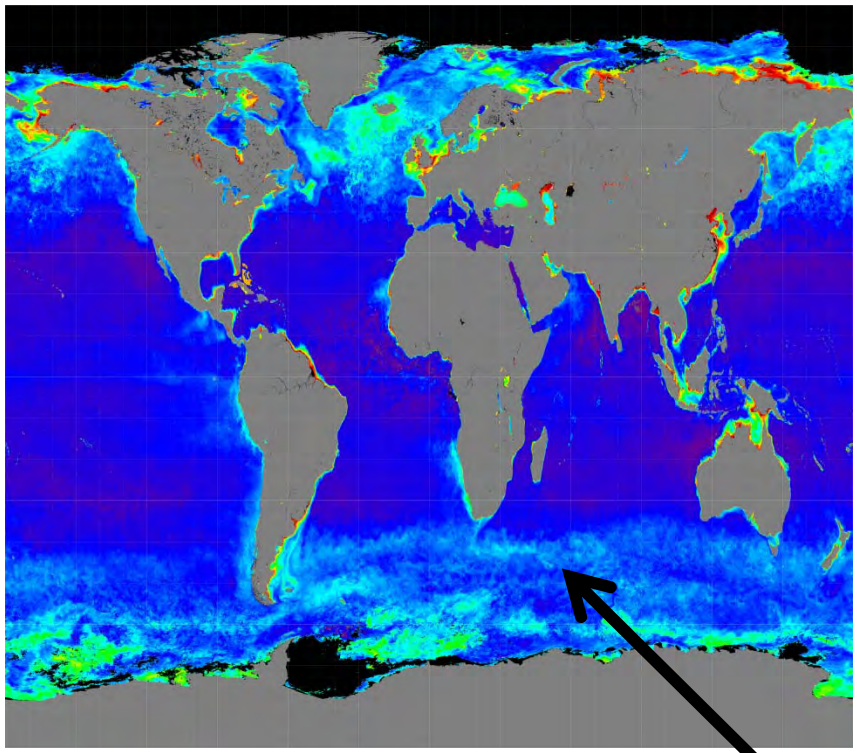
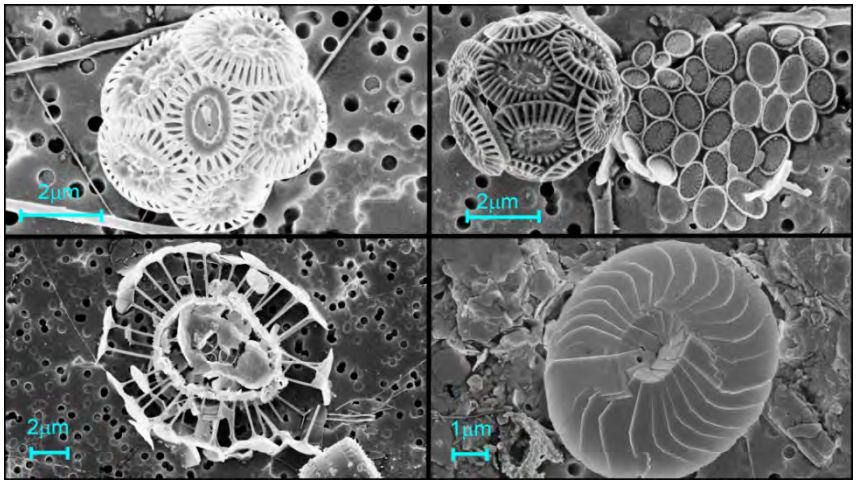
Coccolithophores are strong drivers of ocean biogeochemistry and optics



2014, MODIS AQUA

Emiliania huxleyi

Emiliania huxleyi
Ophiaster sp.

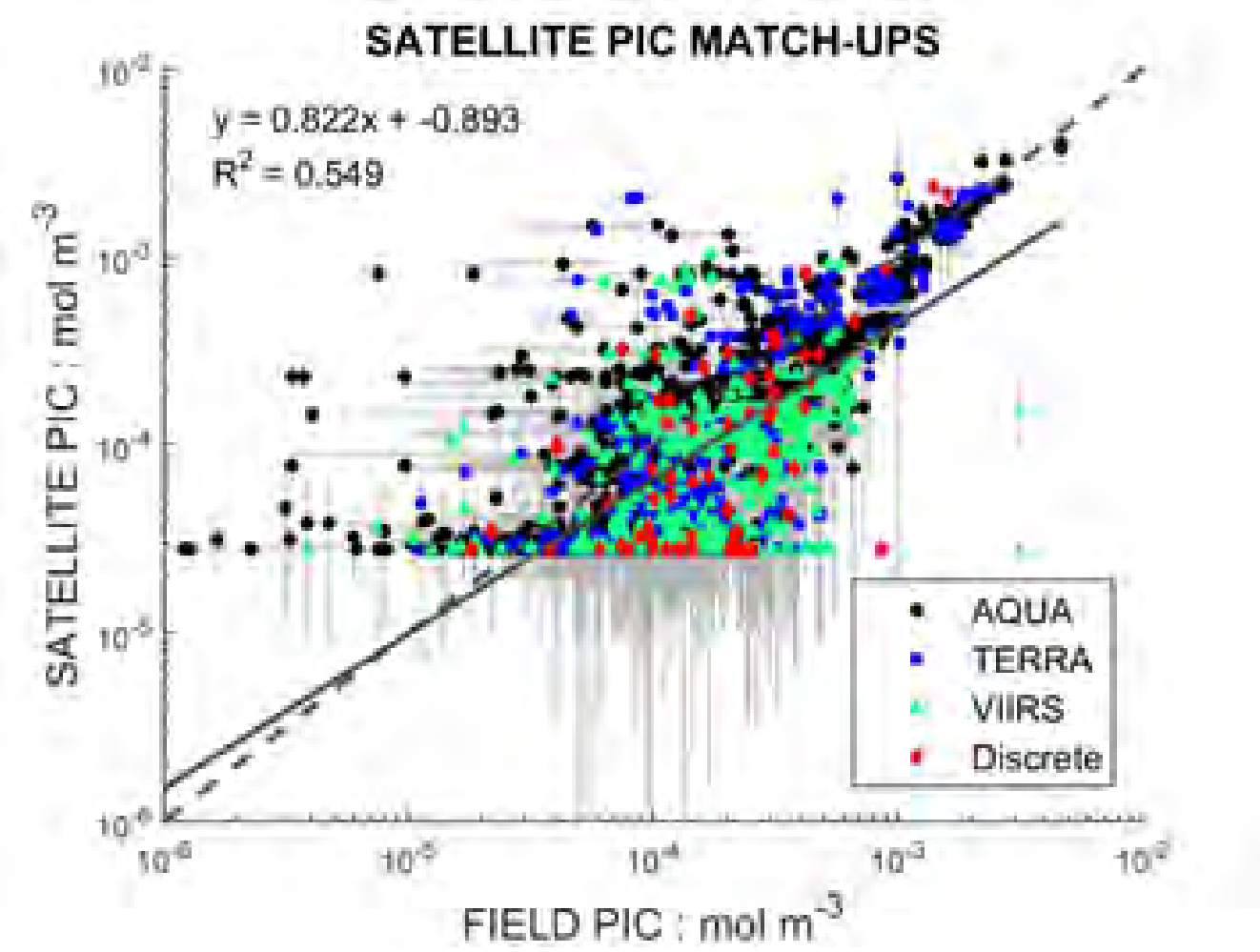


Papposphaera sp.

Calcidiscus leptoporous

Great Calcite Belt

PIC by VIIRS and MODIS

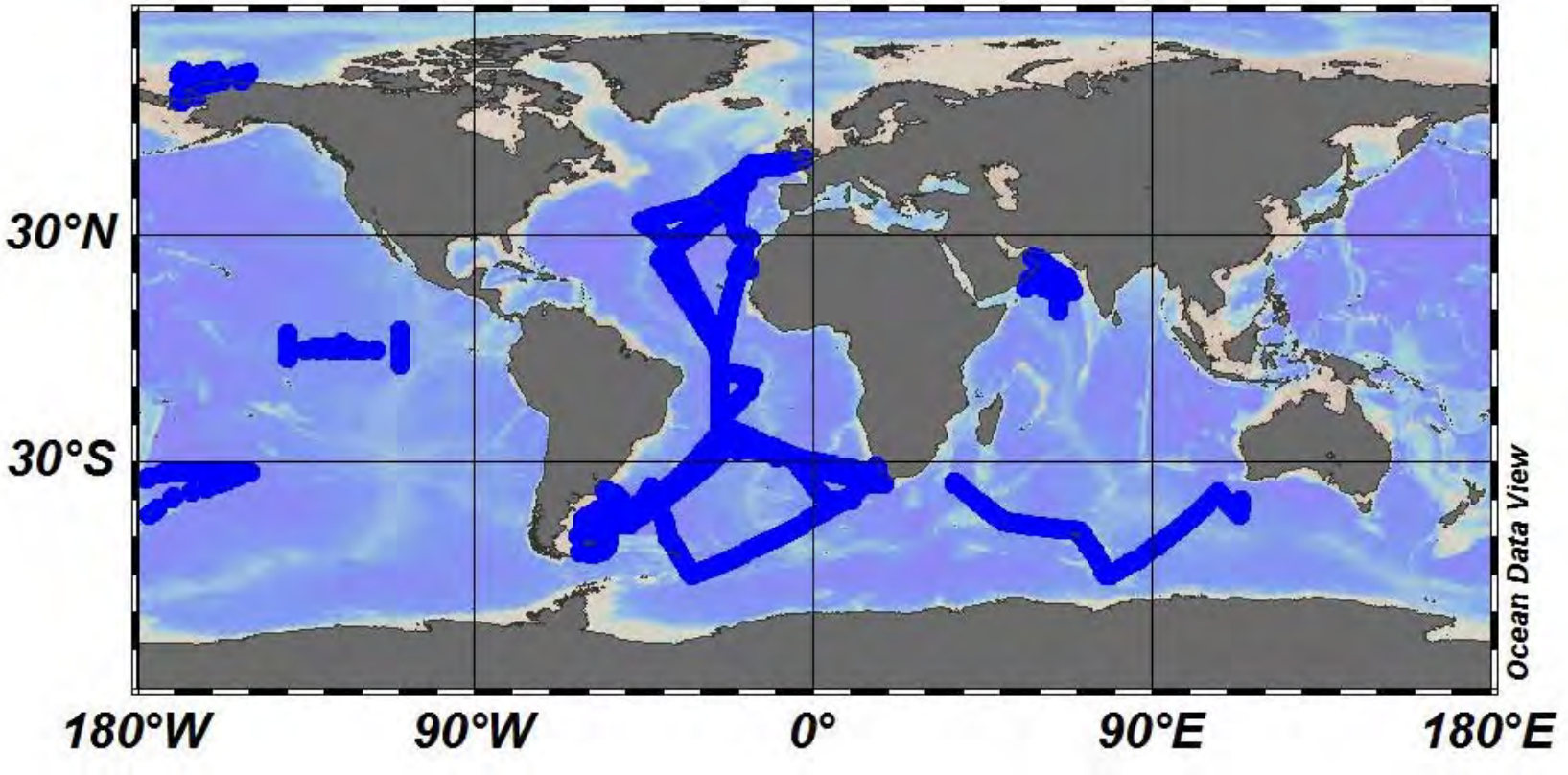


Vignette #1: Scaling from Surface Satellite Measurements of PIC to Integrated Euphotic Estimates over the Global Ocean: **Do Vertical Profiles of Coccolithophores Look Like Vertical Profiles of Chlorophyll?**

Set the scene…

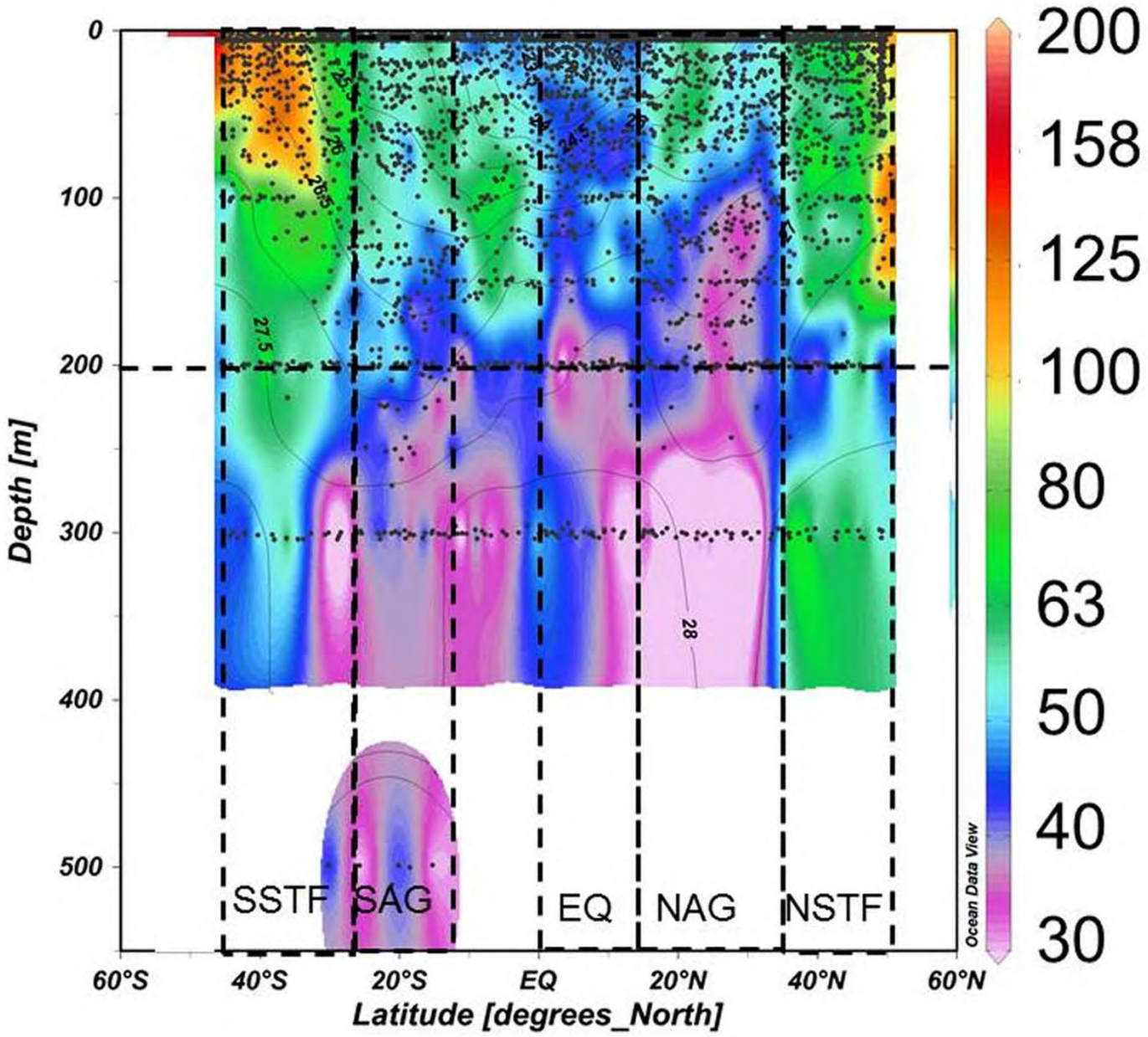
- Deep chlorophyll maxima are the norm… causes are variable (Cullen, 1982; *Can. J. Fish. Aquat. Sci.* 39:791-803).
- Others parameterized integrated chlorophyll based on remote sensing measurements from the top optical depth (e.g. Morel et al., 1988; *J. Geophys. Res.* 93:10749-68).
- **PROBLEM: Little known about vertical distributions of other significant biogeochemical variables, to apply to space-based ocean color measurements from the top optical depth.**

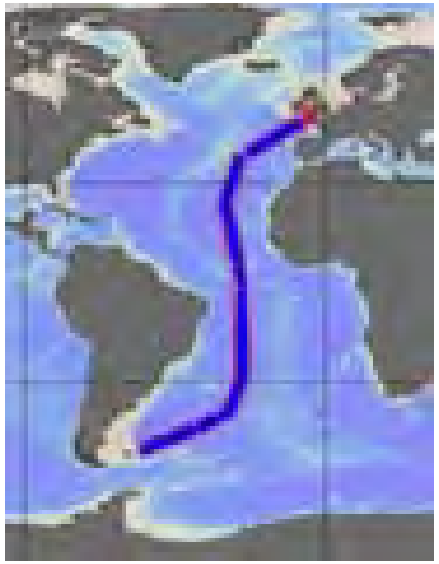
The data set, 15 cruises



N=2,022

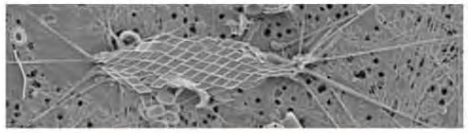
Plated Coccolithophore Cell Conc. (mL^{-1})

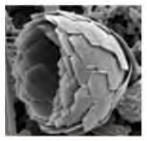


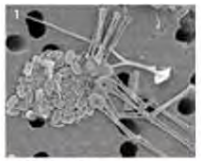


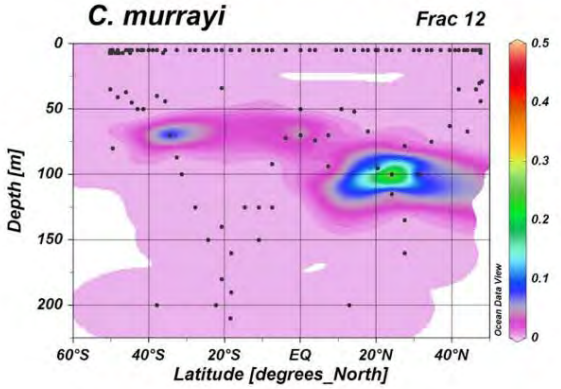
Balch et al. in prep

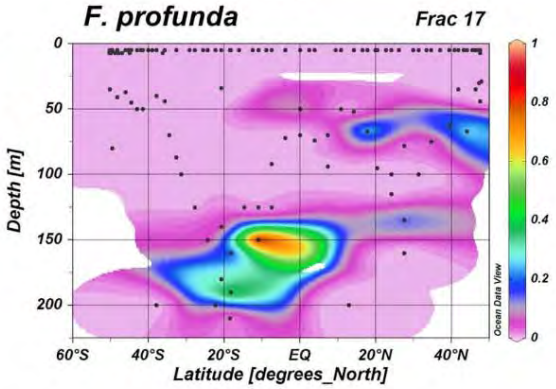
Deep-dwelling coccolithophores

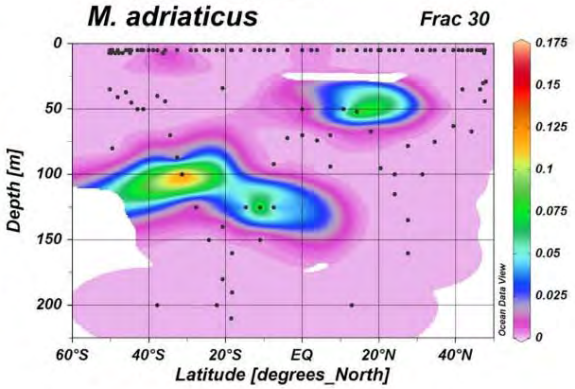


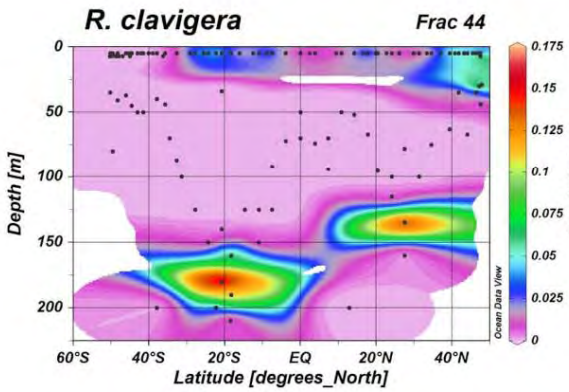


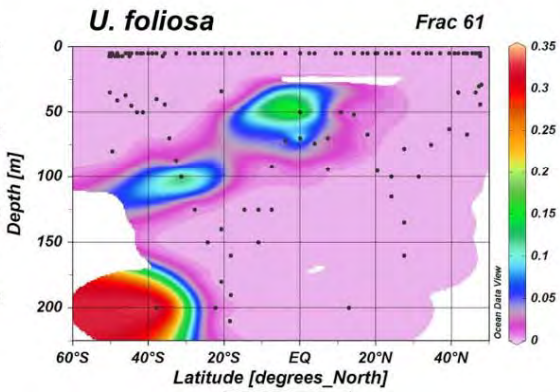


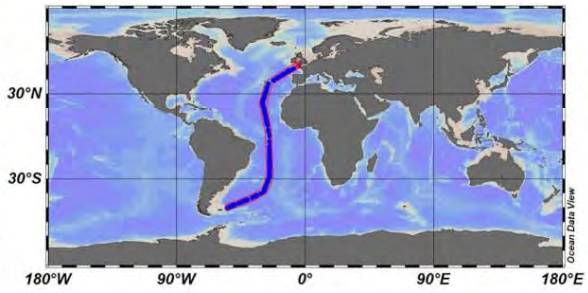


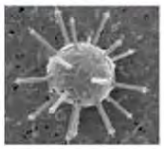












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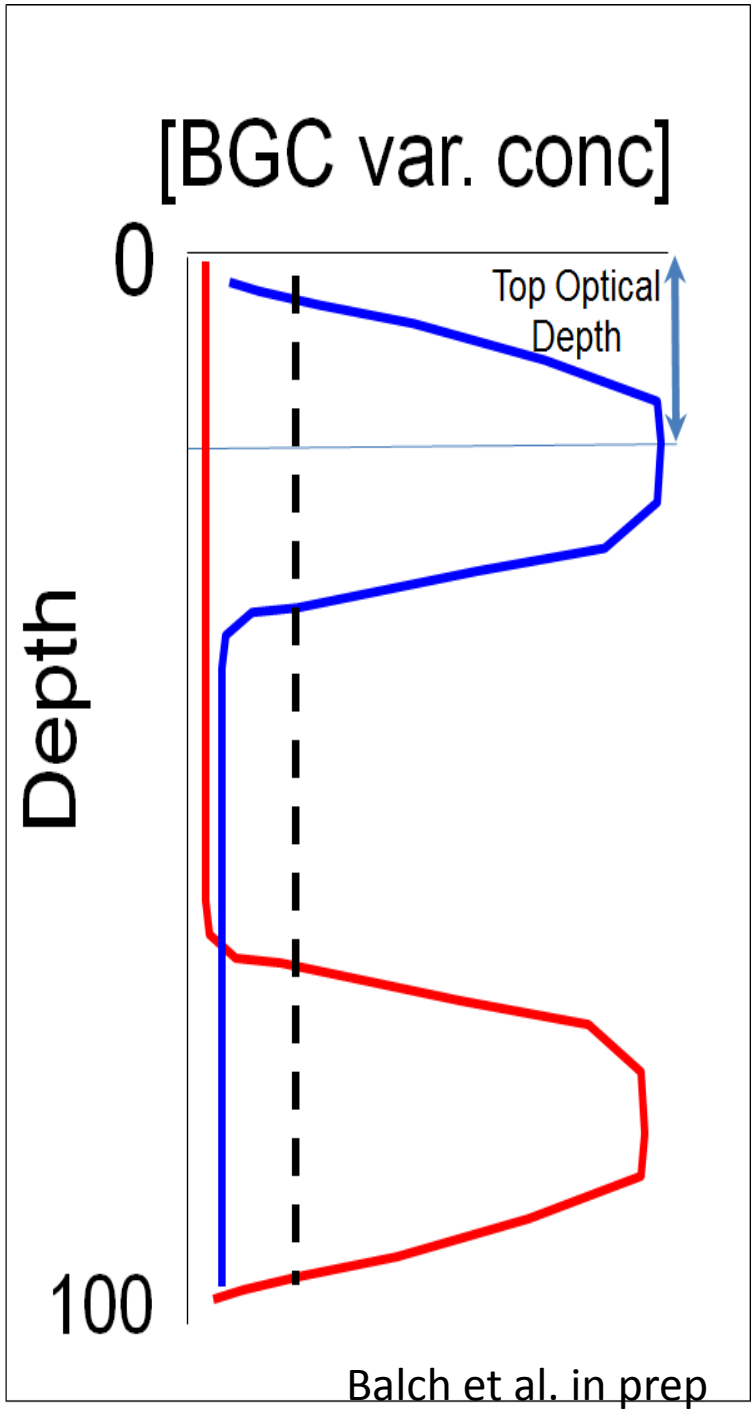
Example- 3 profiles w/ same integral

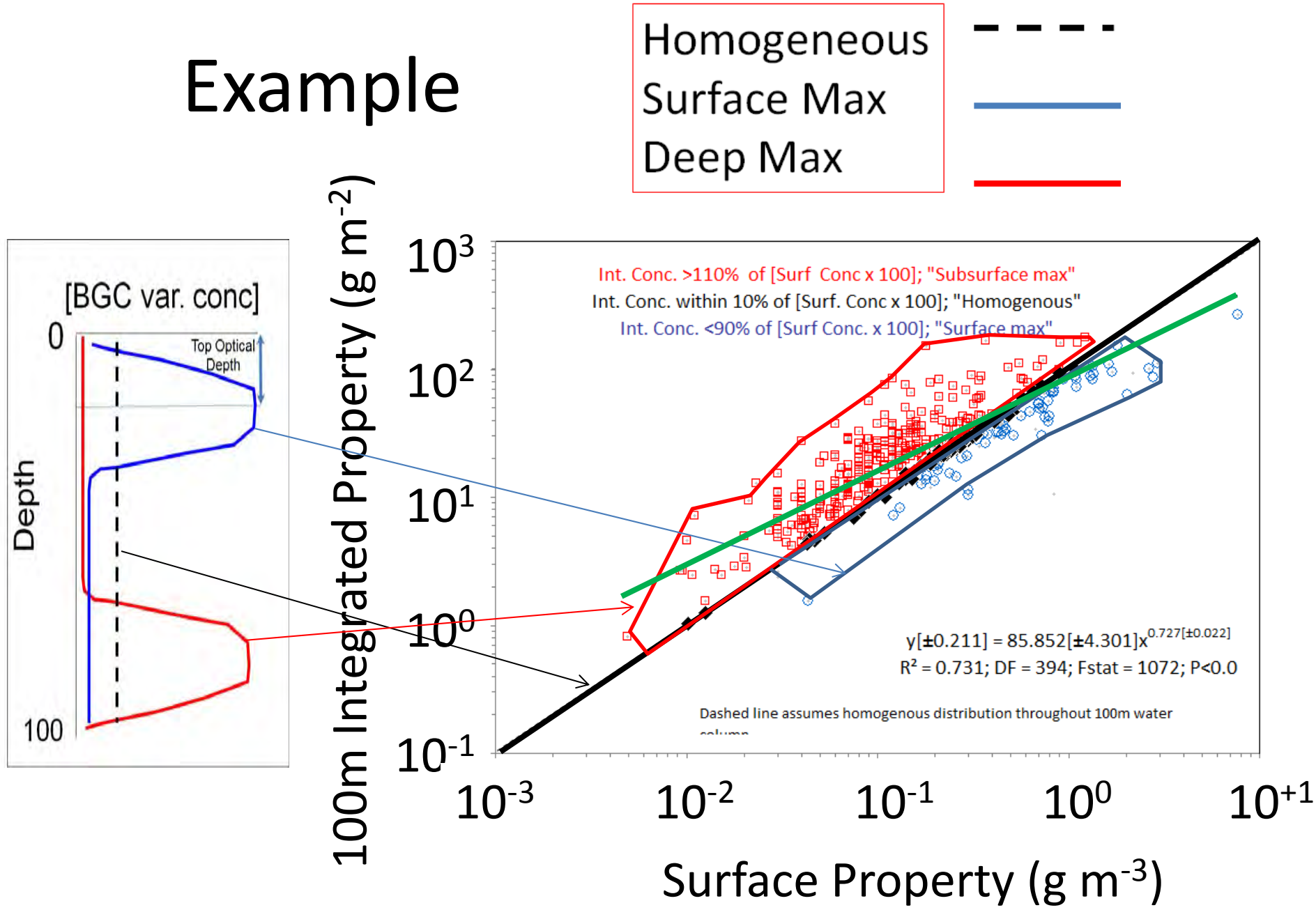
Homogeneous

Surface Max

Deep Max

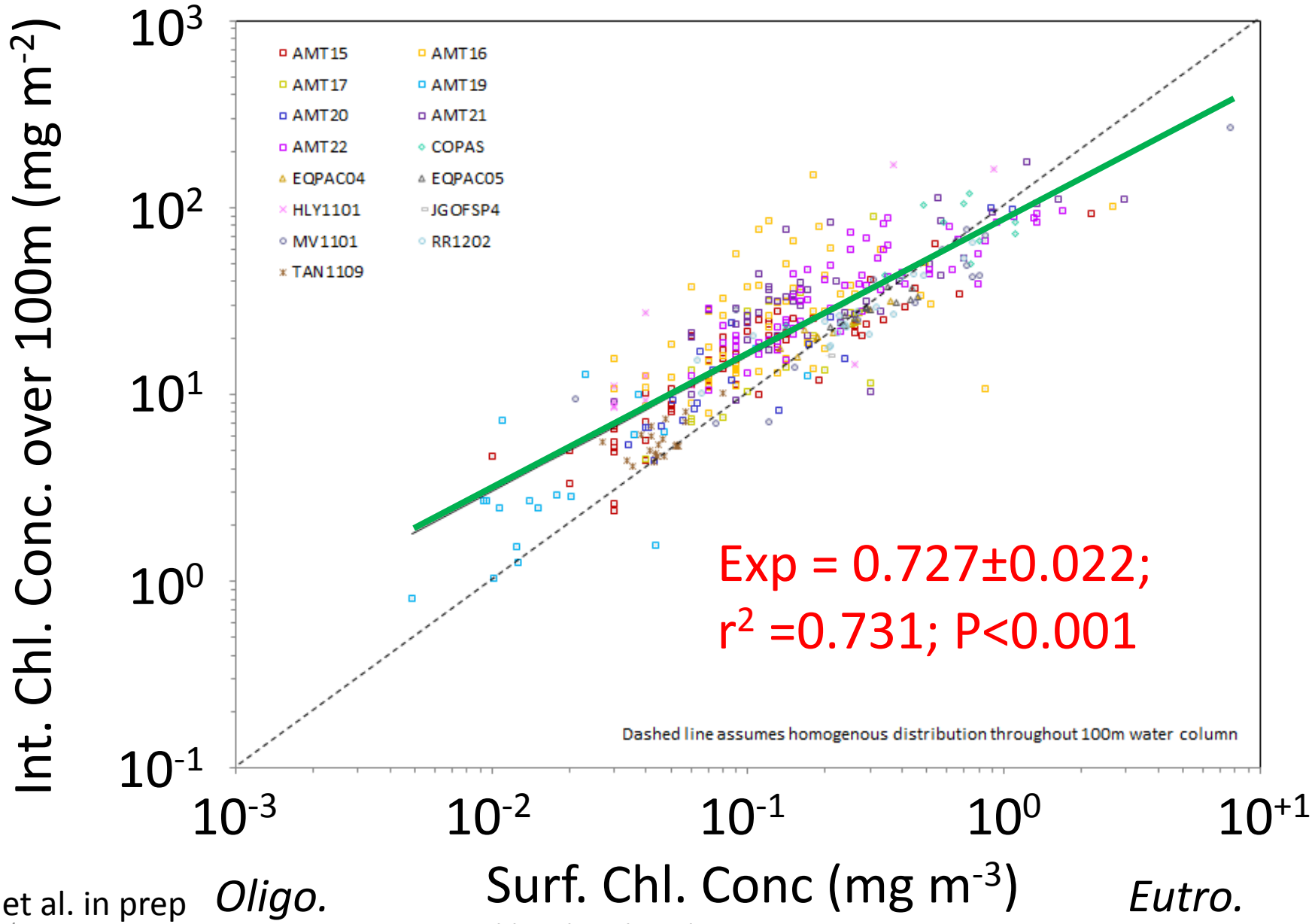


Example



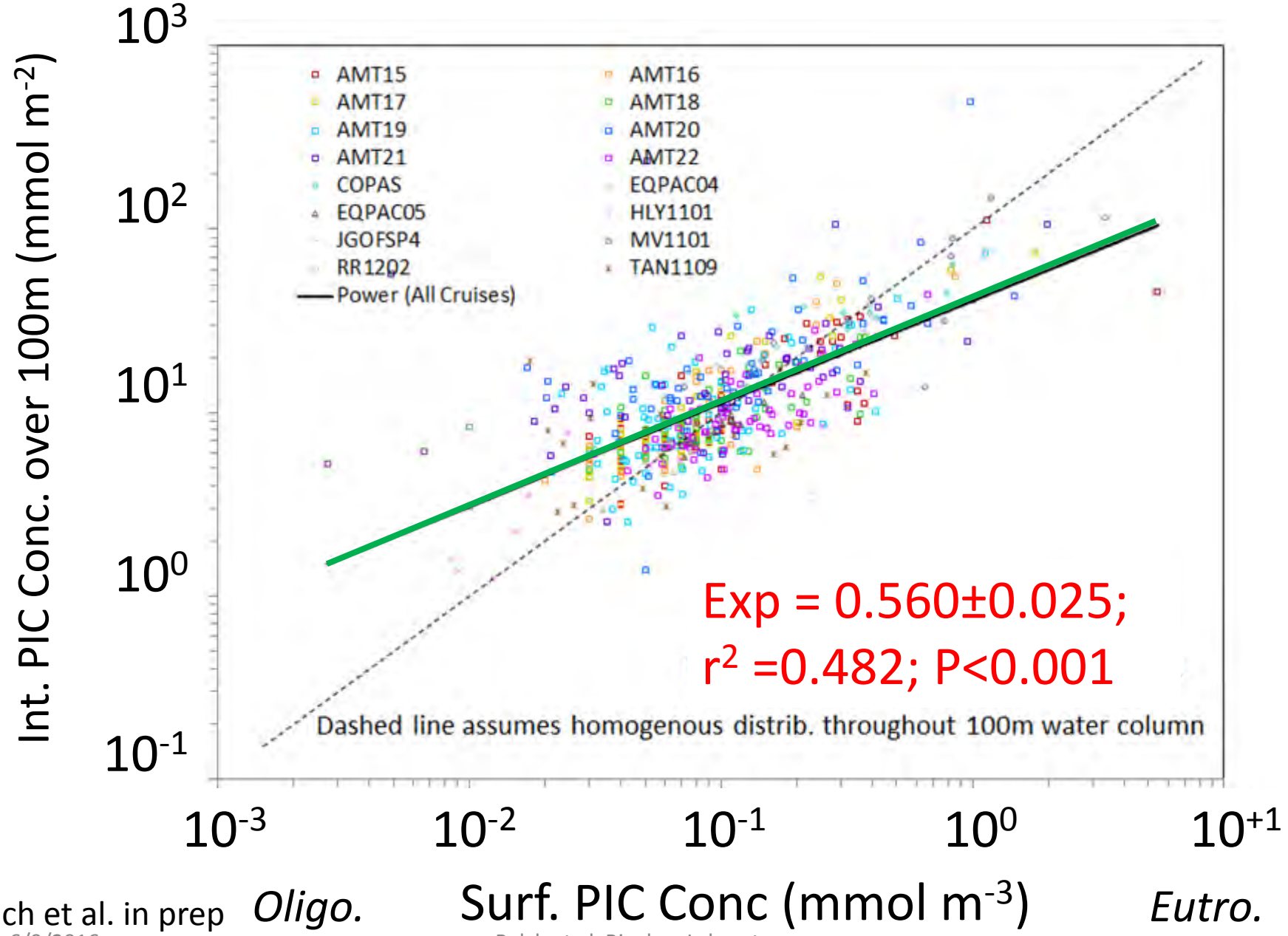
Balch et al. in prep

Chlorophyll



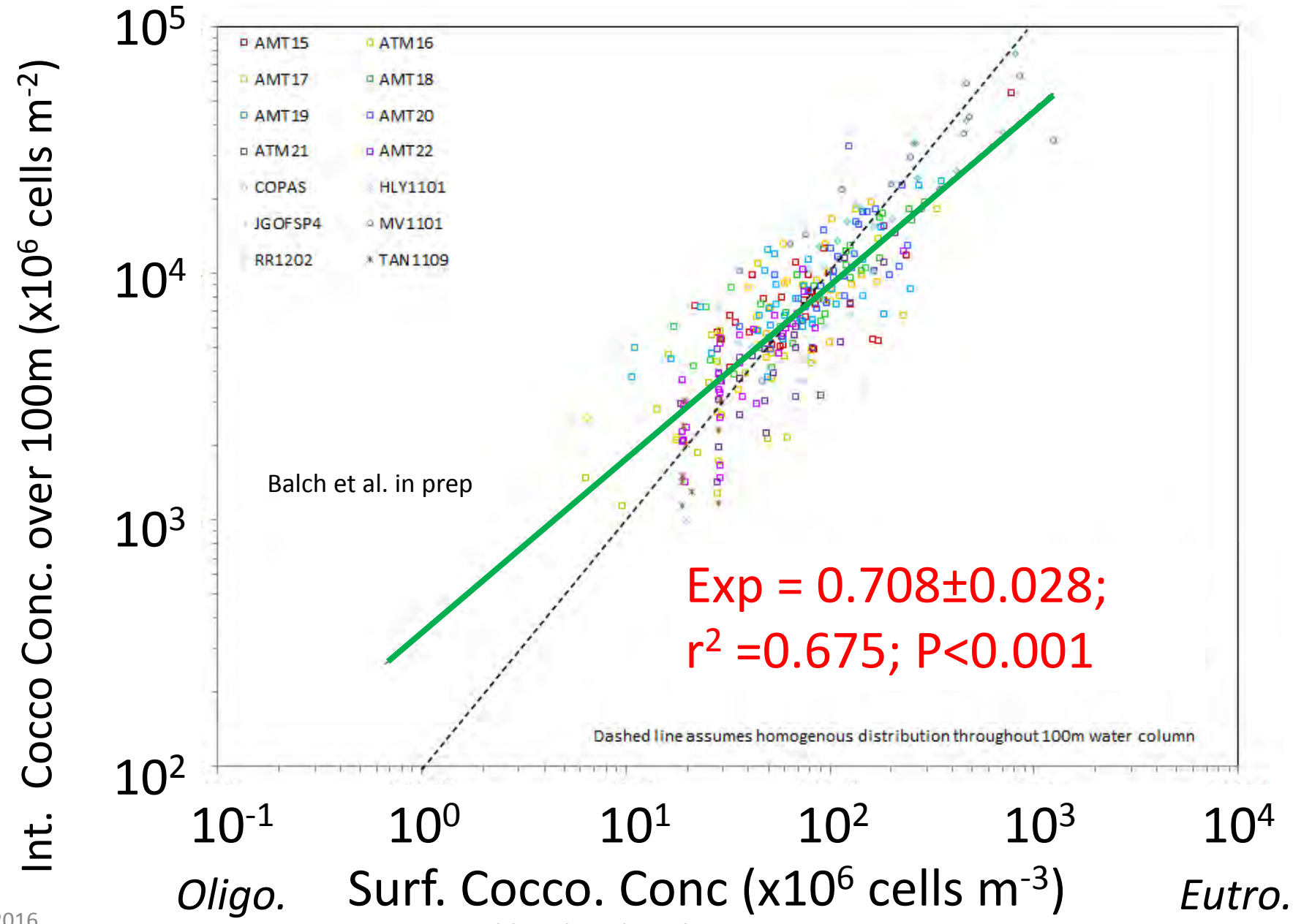
Balch et al. in prep

PIC



Balch et al. in prep

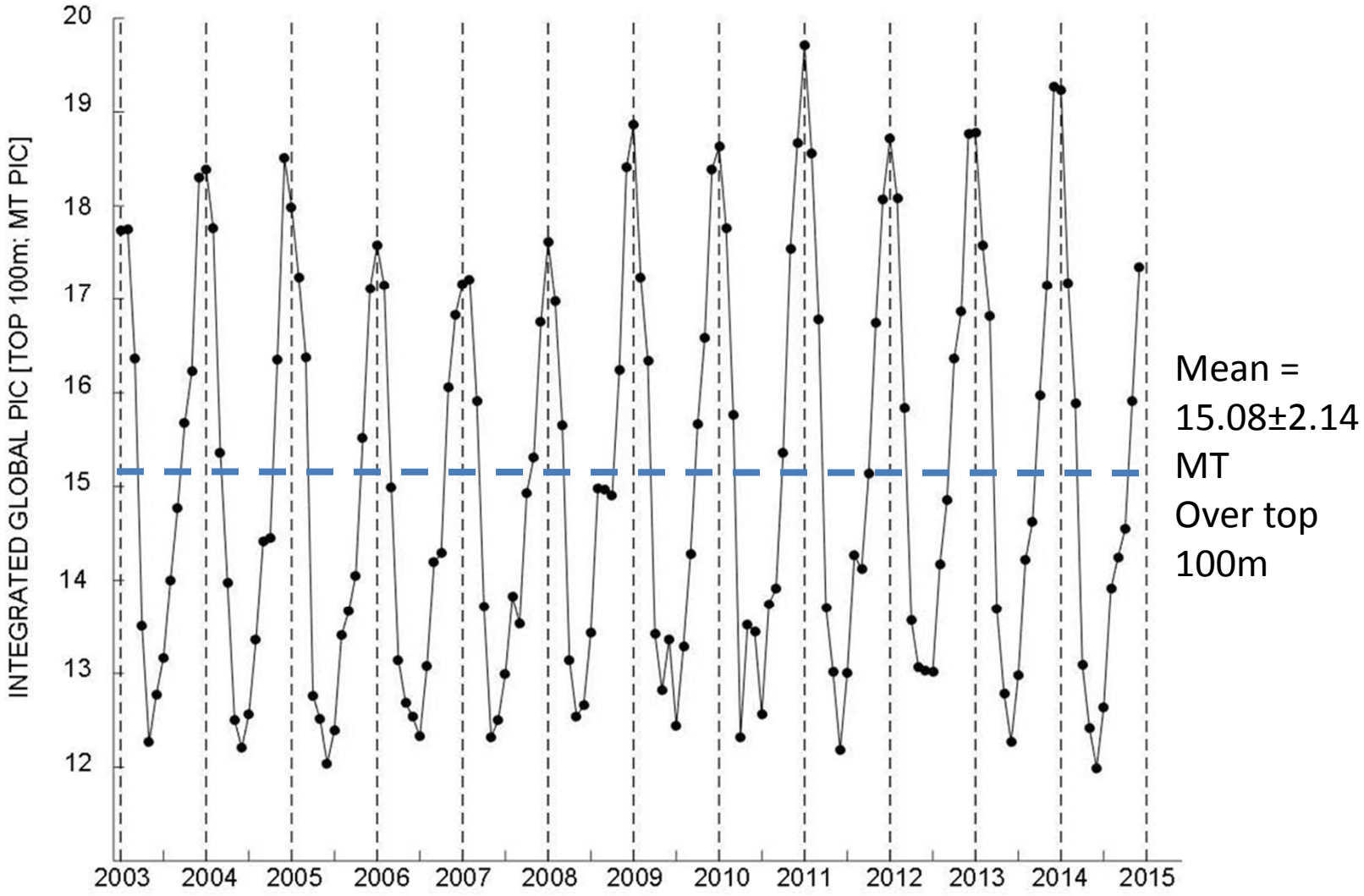
Abundance of plated coccolithophores



Vignette 2: Global PIC trends based on the 2-band/3-band algorithm

Post-doc Jason Hopkins

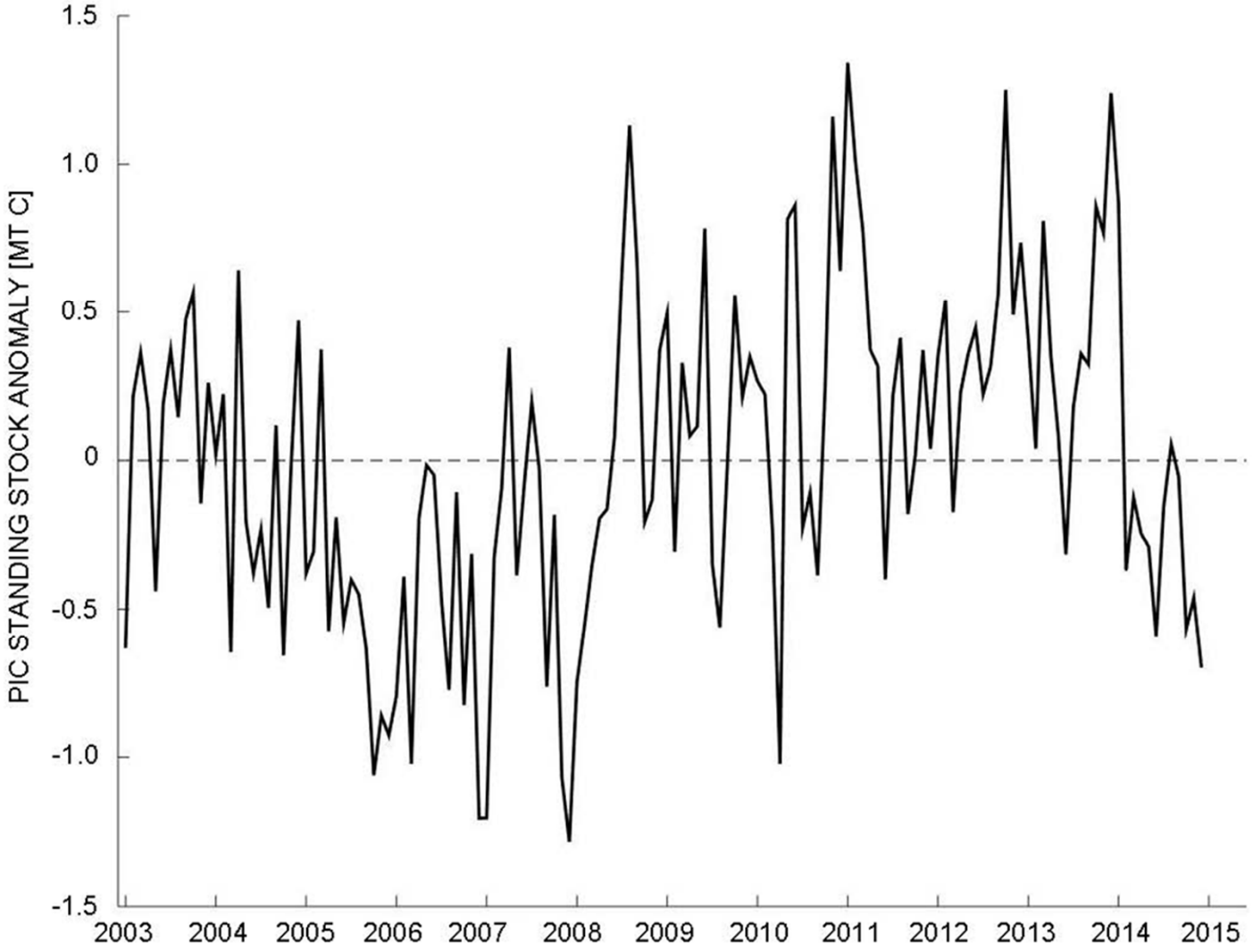
PIC standing stock



Time series of monthly average global PIC standing stock.

Hopkins et al. in prep

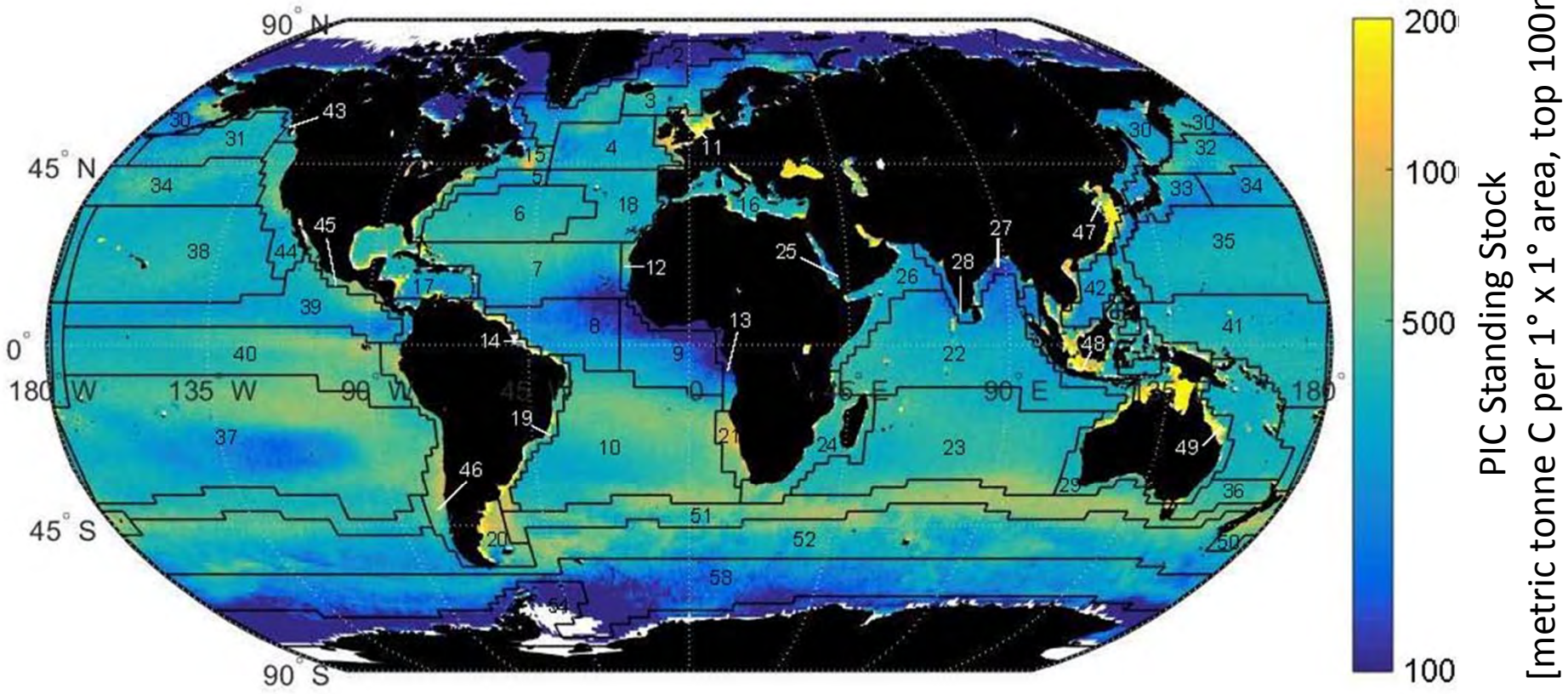
PIC standing stock



Global inter-annual variability in average monthly PIC standing stock

Hopkins et al. in prep

PIC standing stock

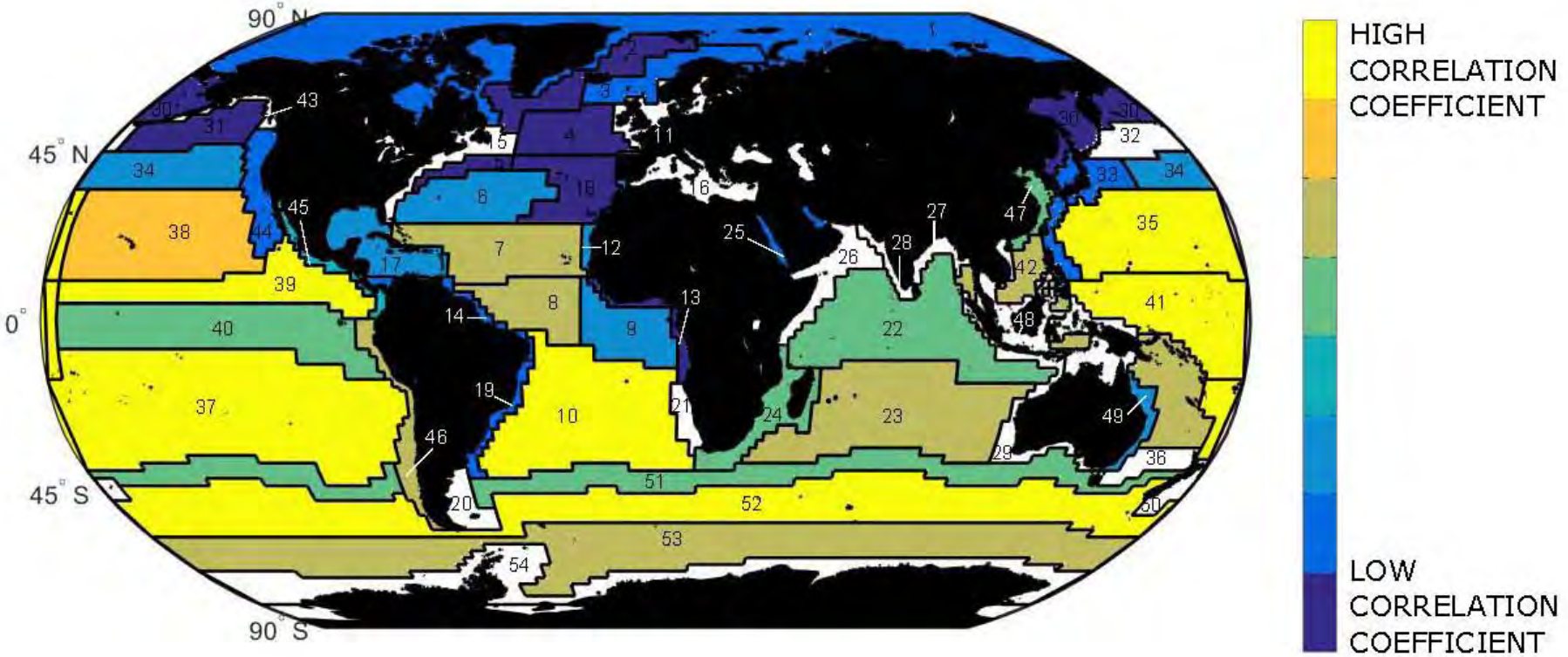


Weighted, monthly PIC standing stock climatology
(2003-2014; all months averaged)

Hopkins et al. in prep

PIC standing stock and correlations to global PIC trends…

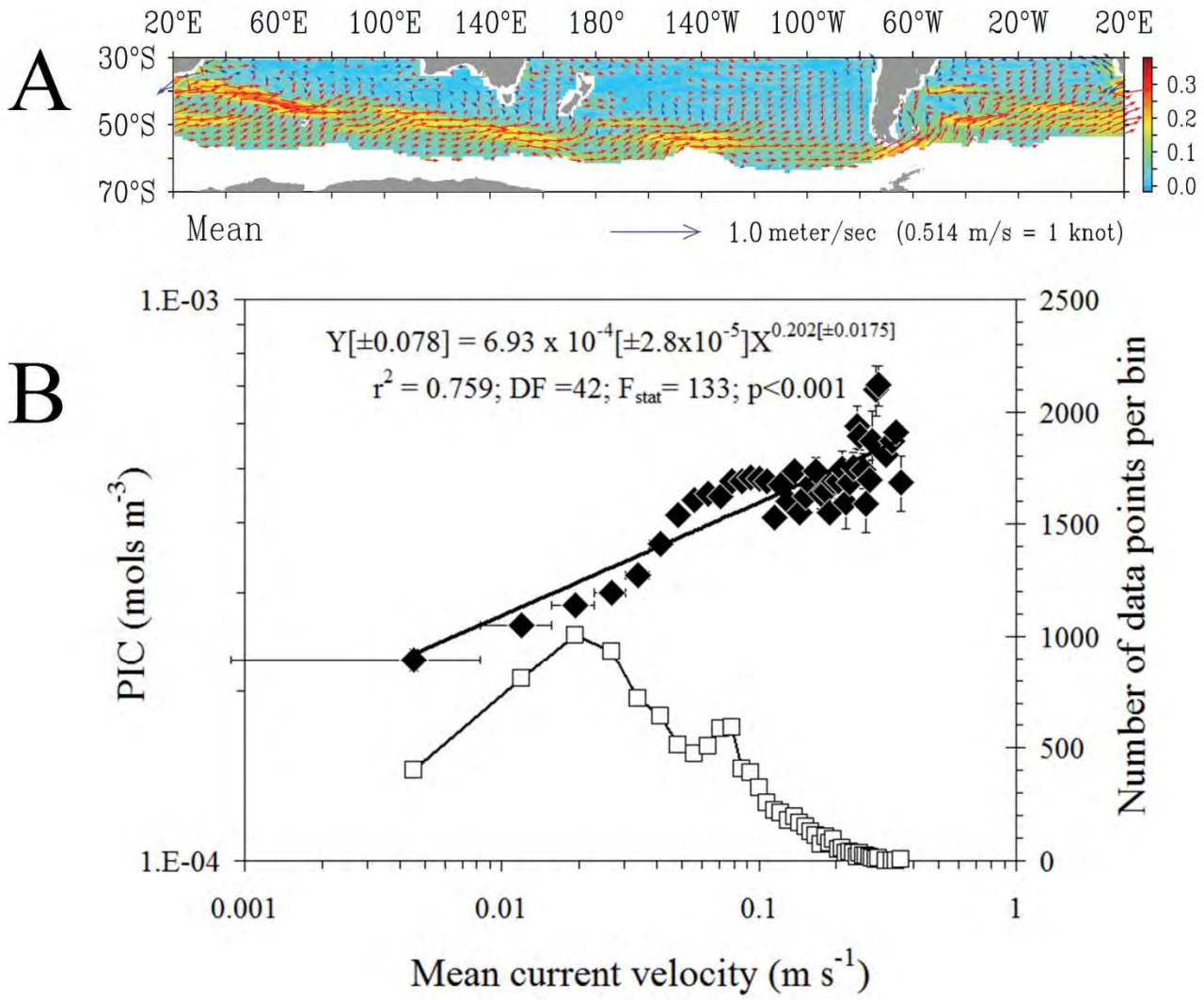
$R^2 = 0.55$



$R^2 = 0.15$

Hopkins et al. in prep

Do current velocities in the Southern Ocean relate to the Great Calcite Belt?



Balch et al., Global Biogeochemical Cycles, in press

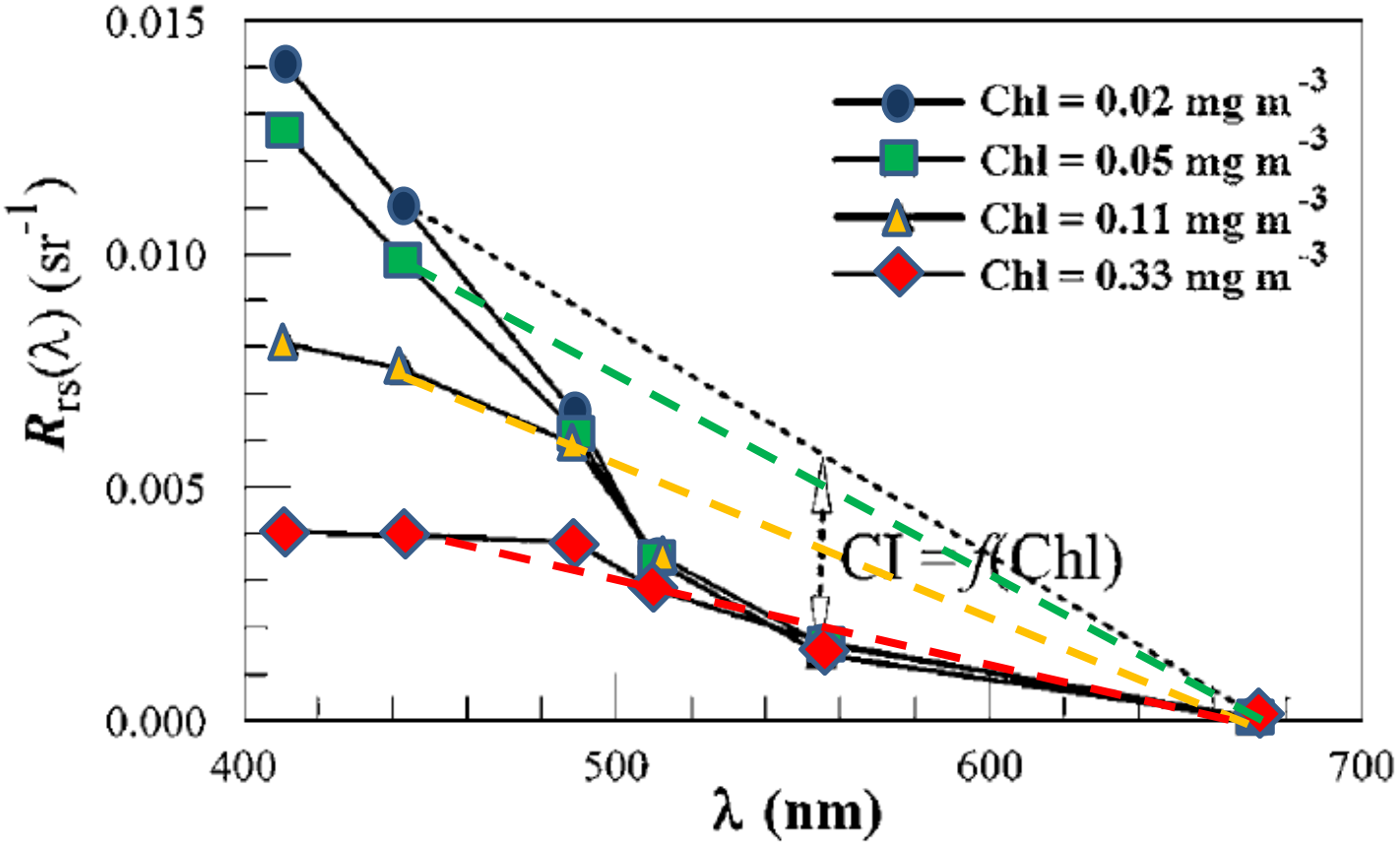
Vignette #3: A new PIC algorithm based on a differencing approach

Post-doc Catherine Mitchell

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, C01011, doi:10.1029/2011JC007395, 2012

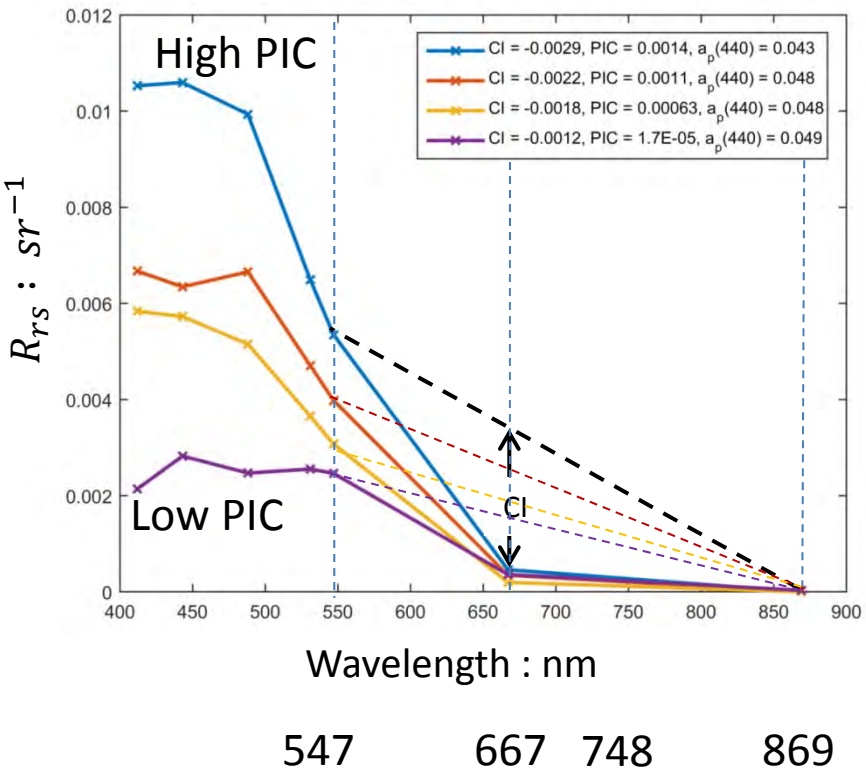
Chlorophyll *a* algorithms for oligotrophic oceans: A novel approach based on three-band reflectance difference

Chuanmin Hu,[1] Zhongping Lee,[2] and Bryan Franz[3]

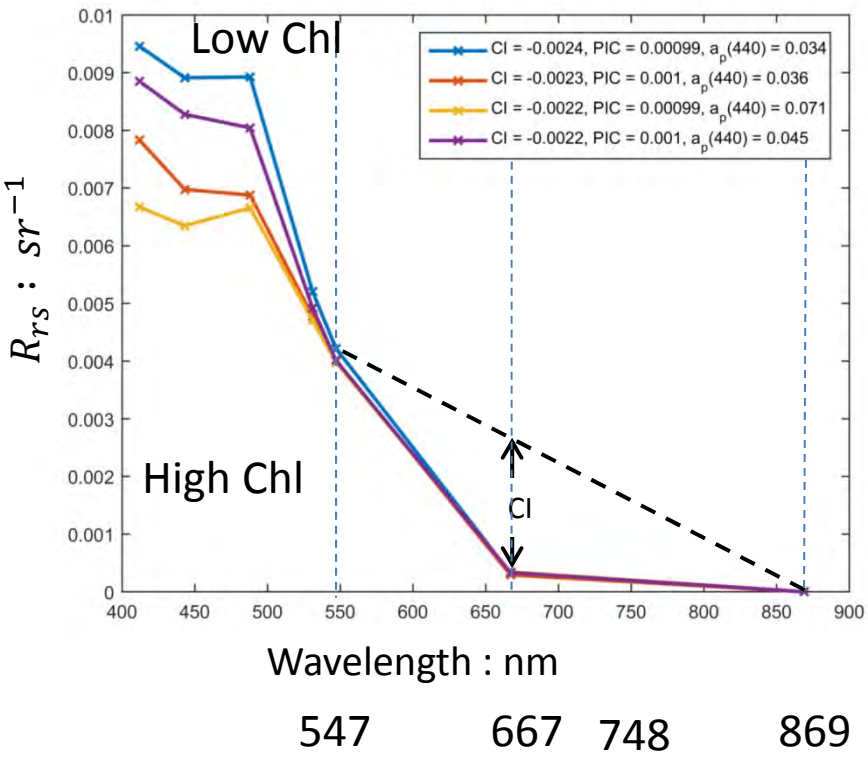


Color Index algorithm for PIC: Proof of concept

Differing PIC concentrations



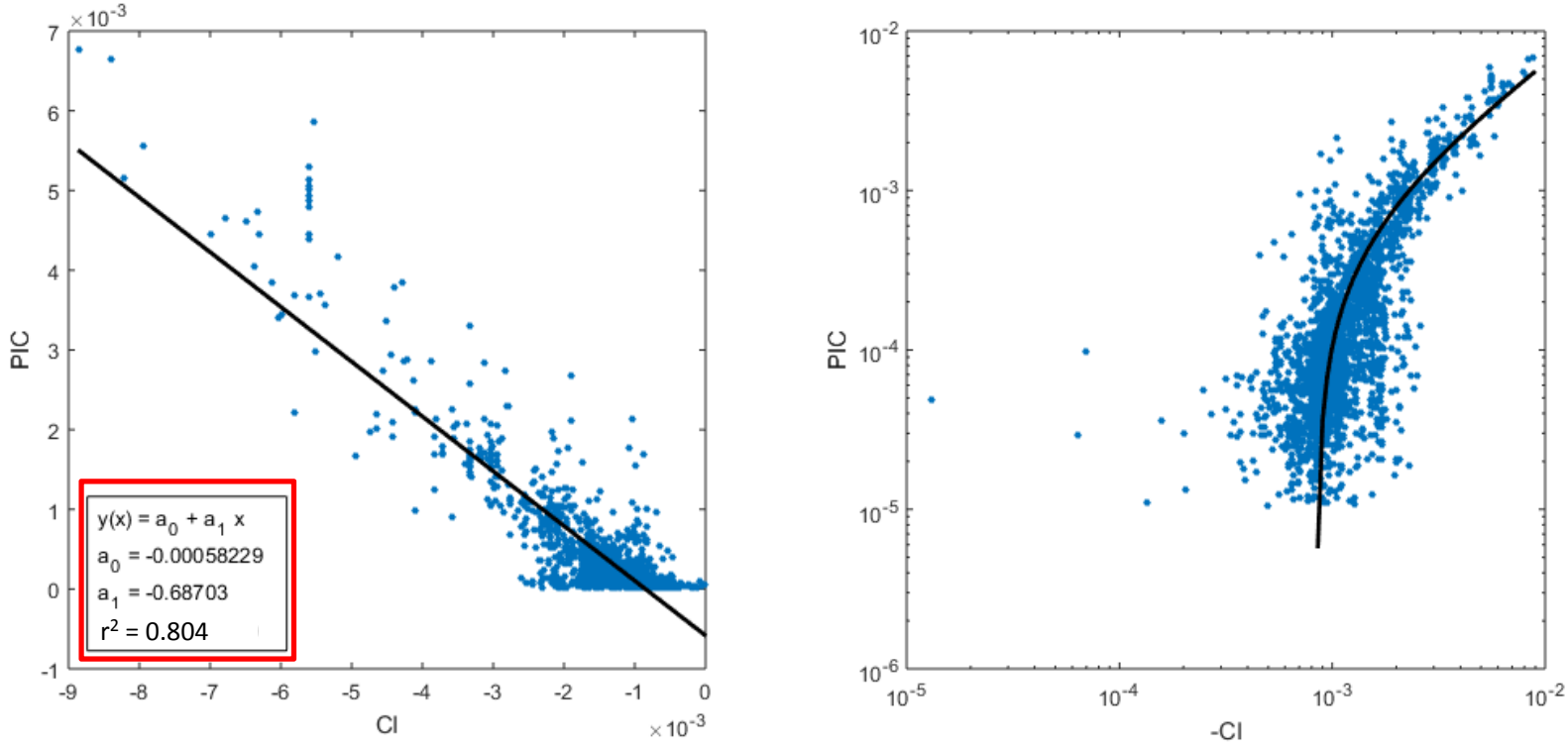
Differing CHL concentrations



Patagonian Shelf, January 2008

Mitchell et al. in prep

Relationship between PIC and color index

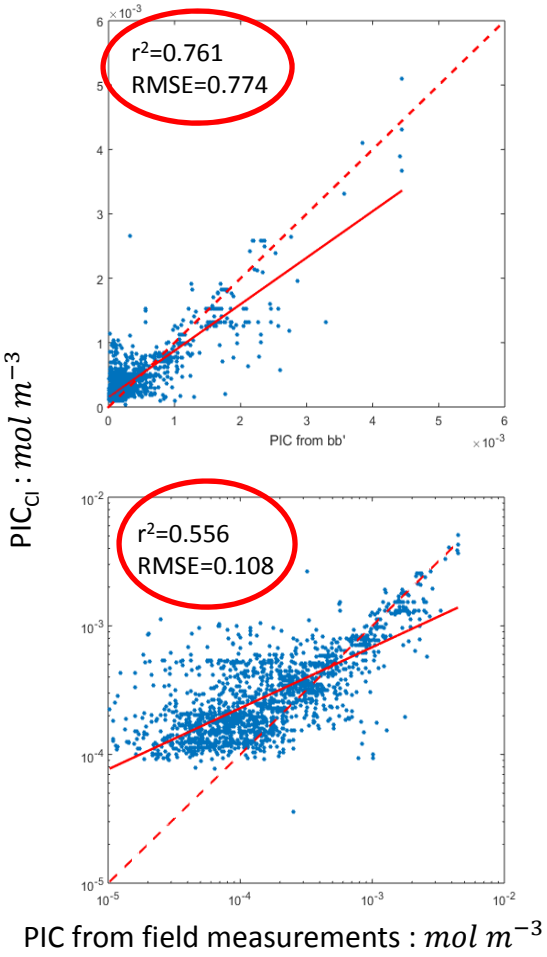


Relationship between field measurements of PIC and CI derived from MODIS Aqua R_{rs} data, shown on both a linear (left hand plot) and logarithmic scale (right hand plot)

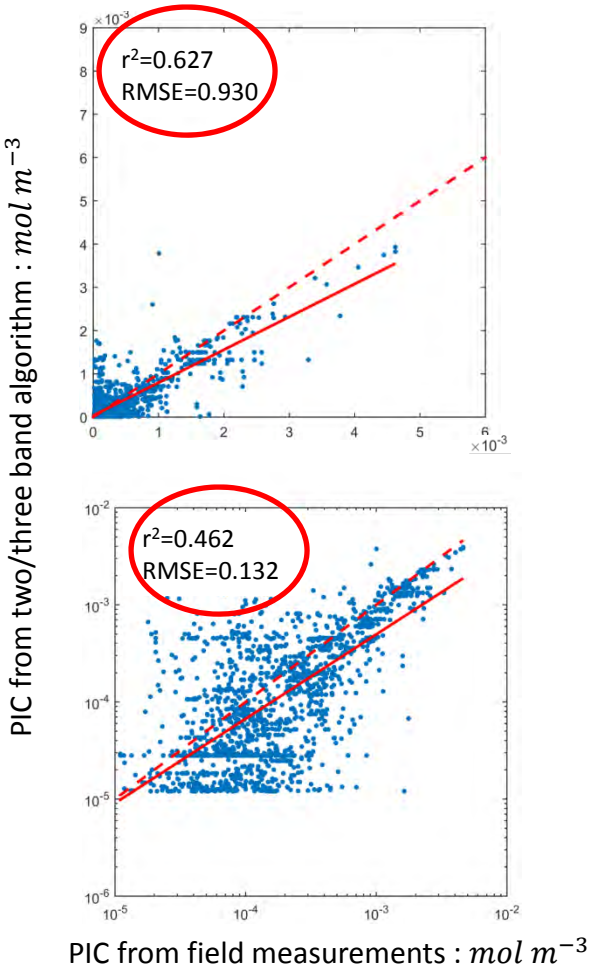
Mitchell et al. in prep

Validation of PIC_{CI} algorithm

a) PIC_{CI} algorithm



b) Current merged two and three band algorithm



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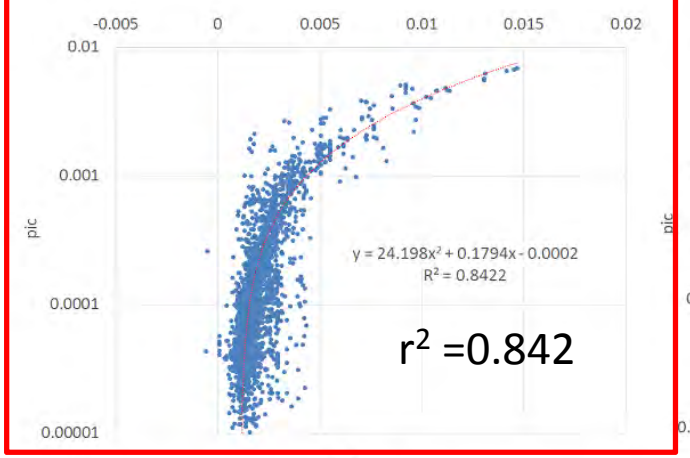
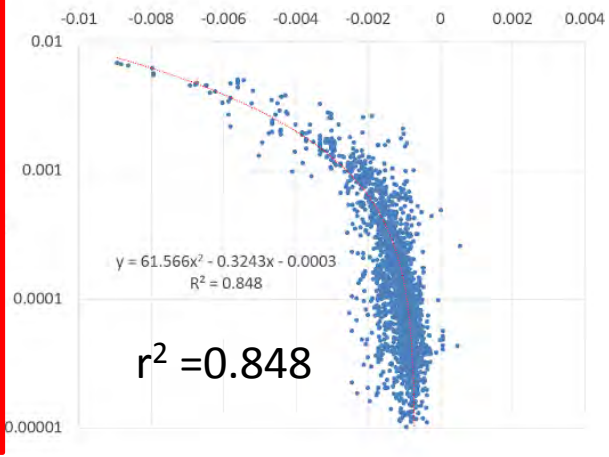
Let's compare three CI-style algorithms: 2-band (547, 667) , 3-band (547, 667, 869) and alternate 3-band (547, 667, 748nm)

CI-2 (547,667)



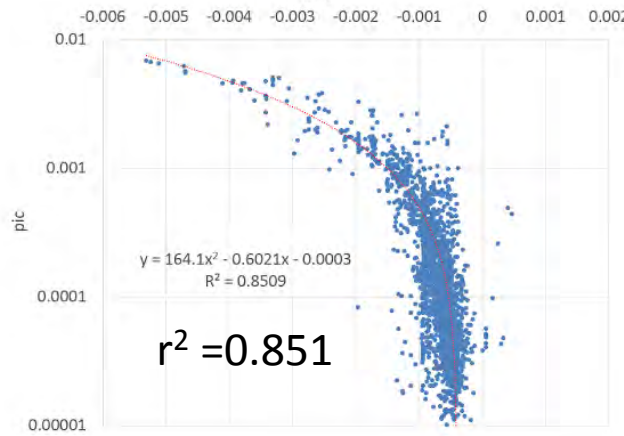
r^2 =0.842

CI-3 (547,667,869)



r^2 =0.848

CI-7



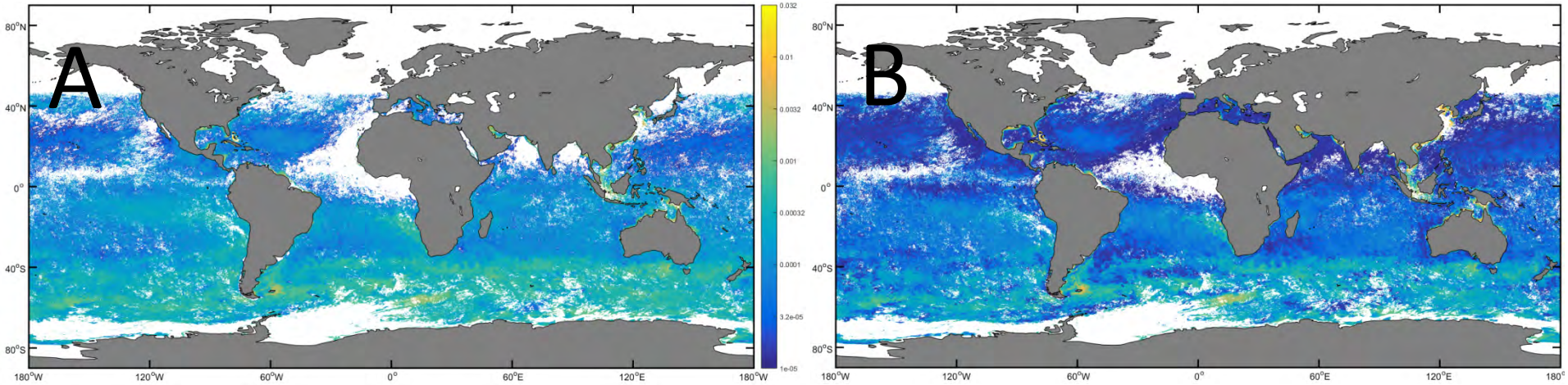
r^2 =0.851

CI-3 (547,667,748)

Application to MODIS Aqua data

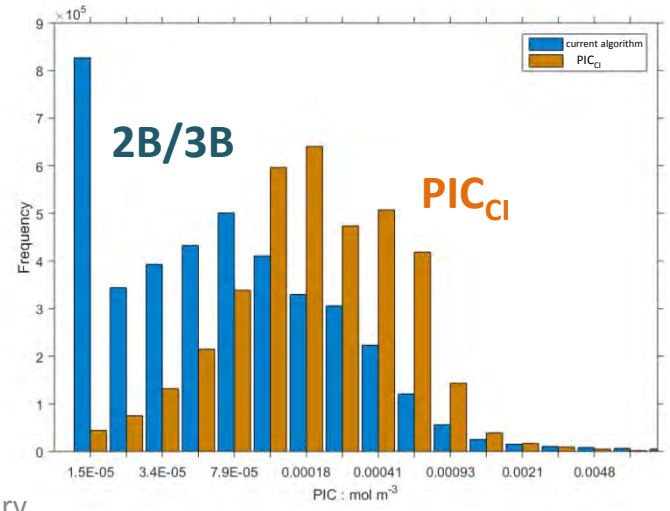
a) PIC from PIC_{CI} algorithm

b) PIC from current merged two and three band algorithm



(a) and (b) Global maps of the average PIC concentration for December 2015 (A and B) and (C) the distribution of the PIC concentration in each of the maps

C



Mitchell et al. in prep

Summary

- Performance of MODIS-A, MODIS-T and VIIRS for PIC all similar.
- We can now statistically account for sub-surface PIC for global imagery, applicable across all levels of productivity
- A new analysis of global PIC shows mean PIC standing stocks of 15.08+/- 2M tons. Anomolies show coherent change but not correlated to NAO, ENSO, PDO, SOI; Southern ocean drives the global trend in PIC
- PIC concentrations in Great Calcite Belt correlated to altimetry-based current velocities
- New two-band CI algorithm for PIC shows good promise, with improved explained variance and accuracy

The Future?

- Prospects for doing BGC from space are <u>good</u> when we can account for 56-86% of variance of 100m integrated property based on surface measurements in top optical depth. Challenge remains to relate the global variability to global climatological cycles
- Encouraging for NASA EXPORTS program!
- New differencing algorithm for PIC needs to be applied as an experimental product
- ***Thank you!***

Acknowledgments

- A. Wyeth, Bigelow Laboratory-
  AMT24 SEMs
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- Phil Boyd, Univ. Tasmania-
  R/V Tangaroa 1109
- NASA- Funding, cruises
- NSF- Funding, cruises